



Mapping Terrestrial Evapotranspiration at Regional to Global Scales

Matt Rodell

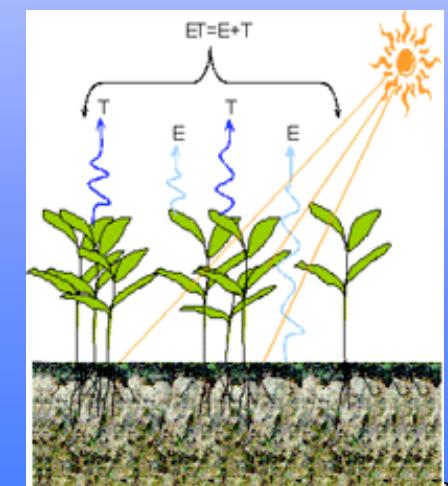
Hydrological Sciences Branch, NASA Goddard Space Flight Center



Evapotranspiration...



- Links the water and energy cycles
 - >50% of solar radiation returned to atmosphere as latent heat (land). ET replenishes atmospheric moisture, leads to precipitation recycling.
- Couples surface and atmospheric processes
 - Land atmosphere interactions
- Causes drought when not compensated by precipitation
- Variations may be indicative of climate change
- **Is the most difficult to measure of the water balance variables**



Man Rodell
Hydrological Sciences Branch, NASA GSFC



Penman-Monteith Equation



$$ET = \frac{\Delta(R_n - G)}{\lambda[\Delta + \gamma(1 + C_d u_2)]} + \frac{\gamma \frac{37}{T_a + 273.16} u_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d u_2)}$$

Δ = slope of saturation vapor pressure curve at mean T_a

R_n = net radiation

G = soil heat flux

γ = psychrometric constant

T_a = mean air temperature

u_2 = wind speed at 2 m

e_s = saturation vapor pressure at T_a

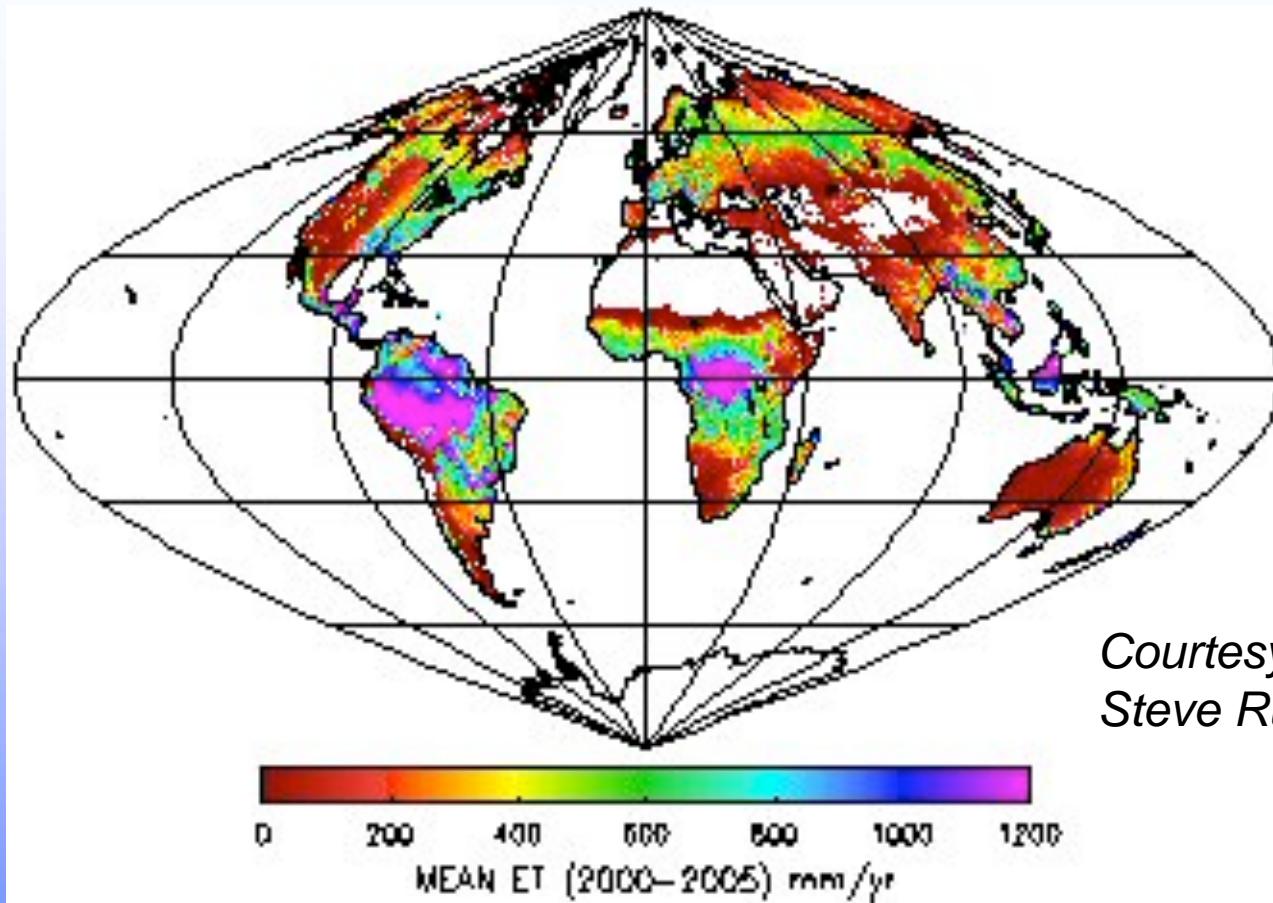
e_a = actual vapor pressure at T_a

λ = latent heat of vaporization

C_d = bulk surface resistance and aerodynamic resistance coefficient



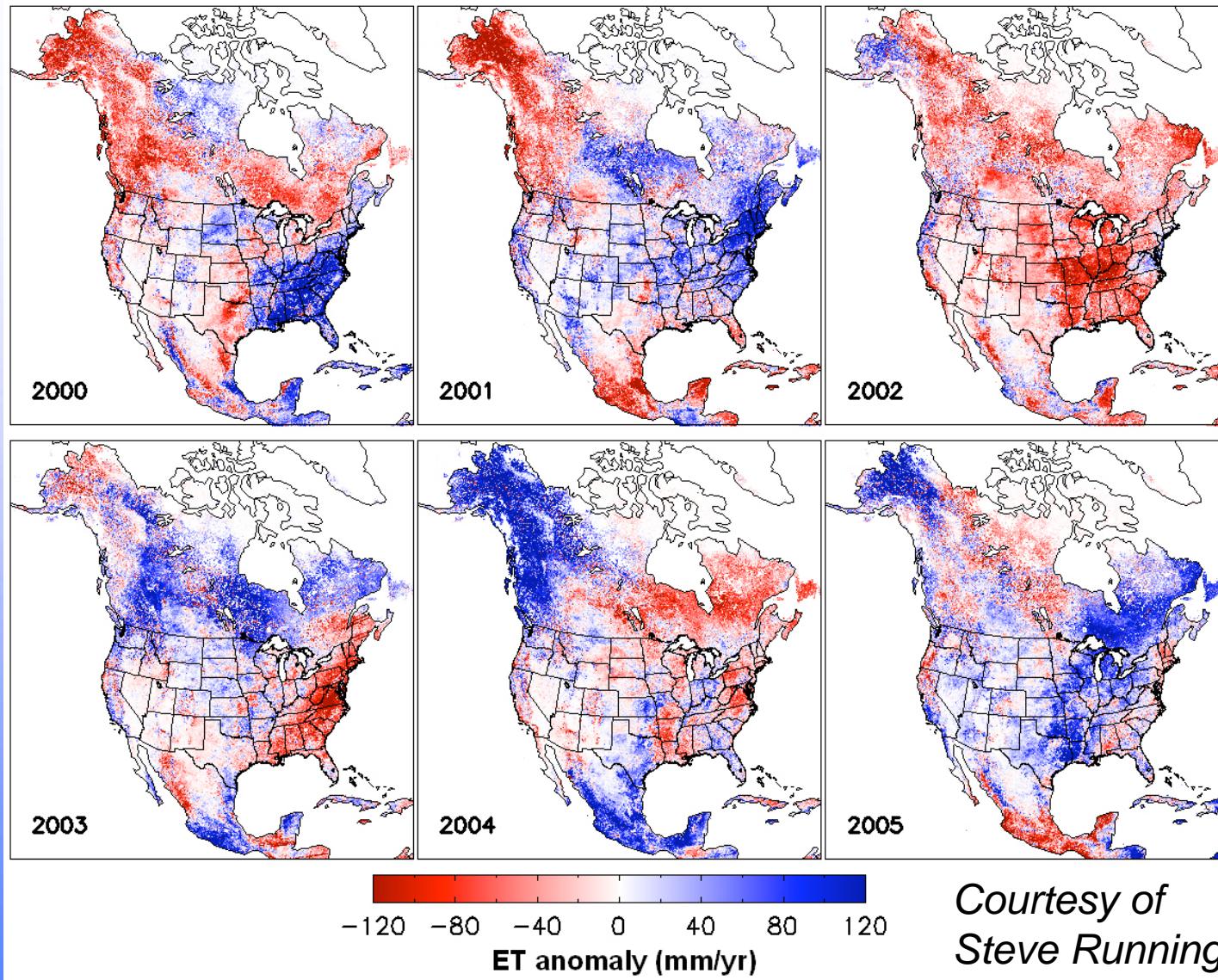
MODIS MOD16 ET Product



- Derived primarily from MODIS data using the Penman-Monteith equation



MODIS MOD16 ET Product



Matt Rodell
Hydrological Sciences Branch, NASA GSFC



Surface Energy Balance Model (SEBS)



Latent heat flux calculated as a residual of the surface energy balance equation:

$$LE = R_n - H - G$$

- R_n is computed from shortwave, longwave, and surface temperature measurements
- H is estimated using similarity theory, with wind, air temperature, humidity, and roughness data
- G is parameterized as a function of fractional cover – LAI/NDVI relationships



Princeton's MODIS (SEBS) ET Product



- Most of the data required for SEBS can be retrieved from MODIS, CERES, and AIRS
- Princeton developing a global product

Courtesy of
Eric Wood

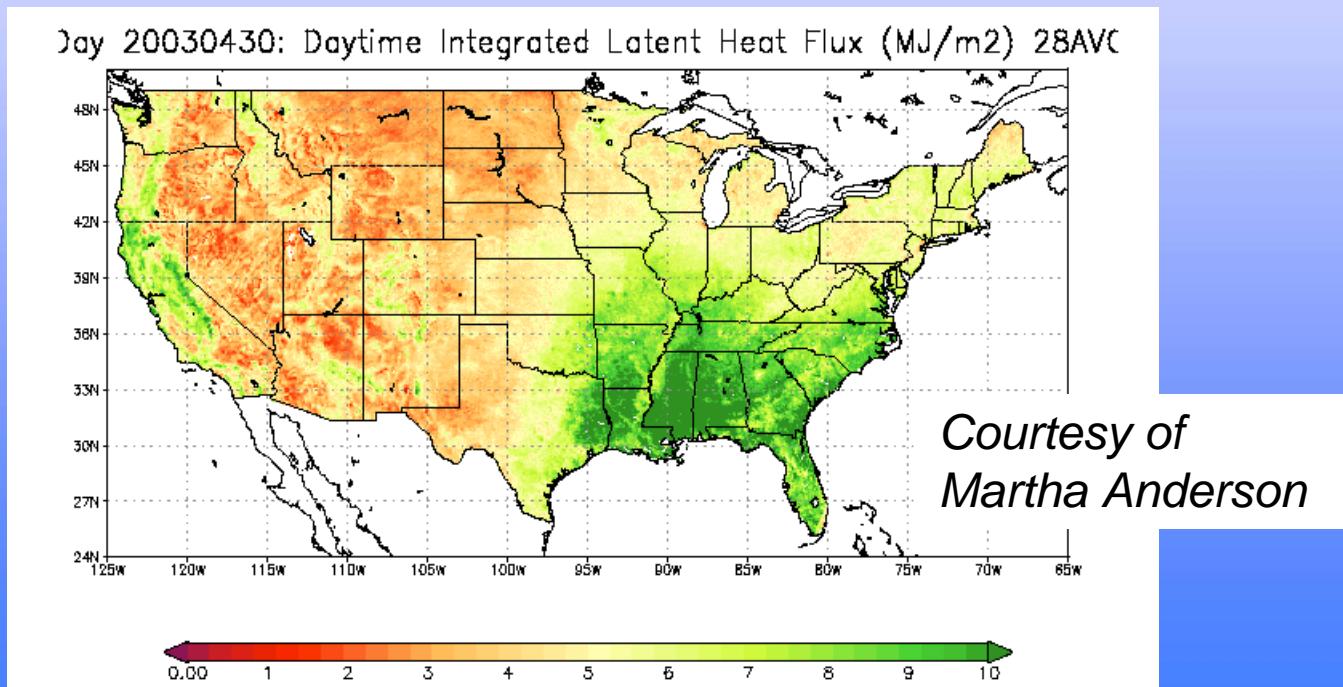
Retrieved ET over Oklahoma. Left: MODIS data products, MODIS radiation, and AIRS meteorology. Right: CERES radiation and surface temperature, AIRS meteorology, and MODIS land products.



USDA's ALEXI (Two Source) ET Product



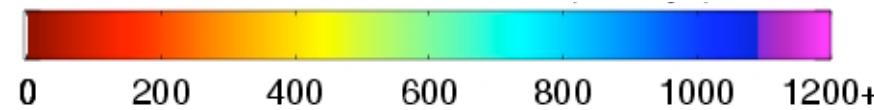
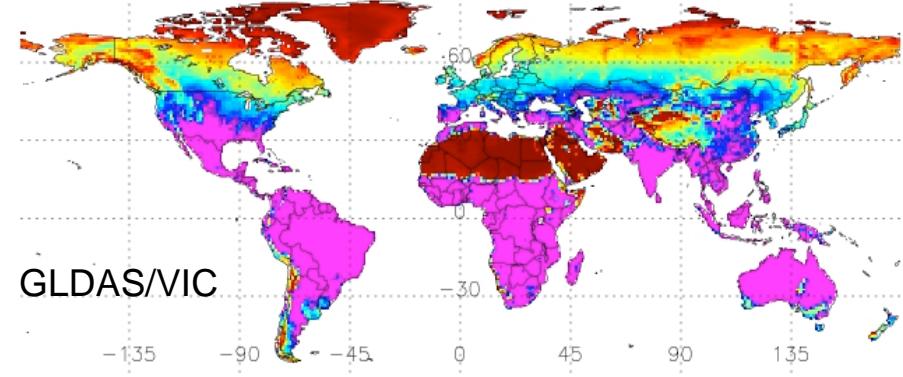
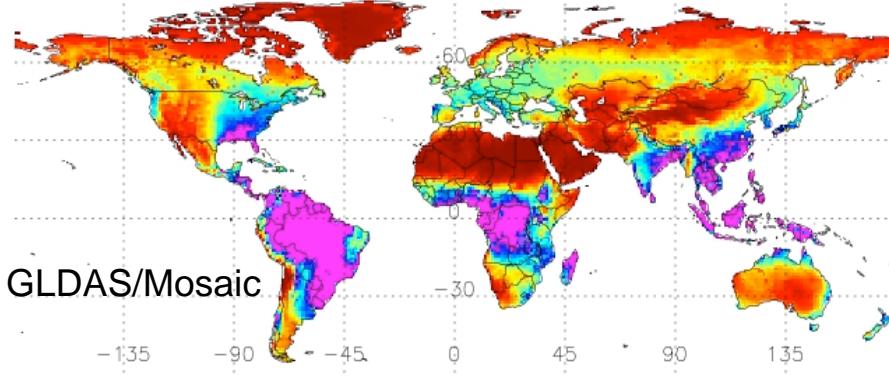
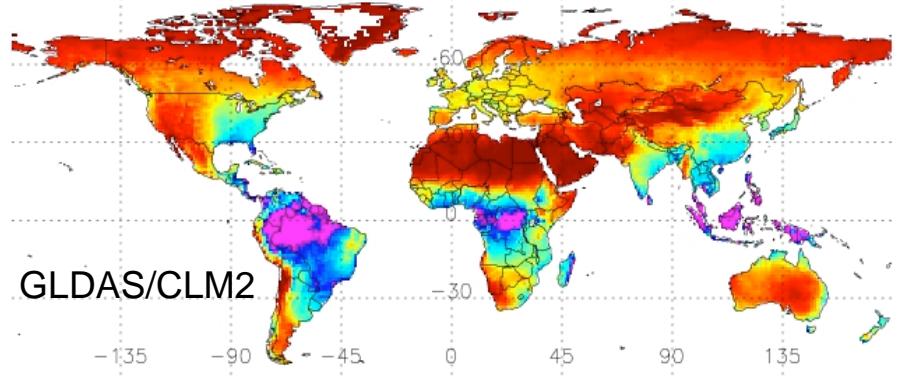
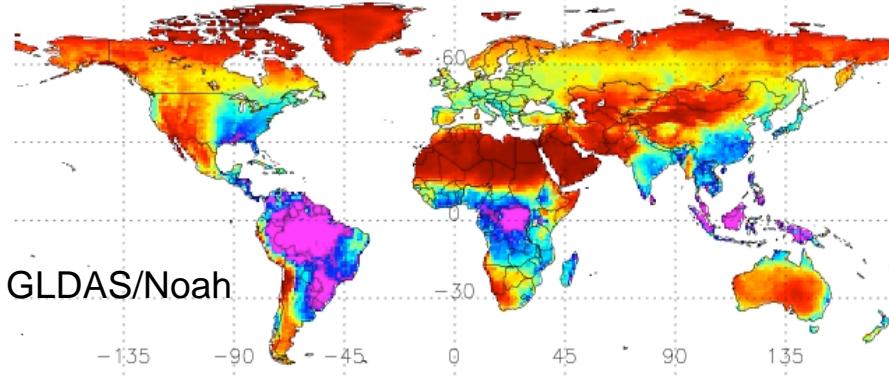
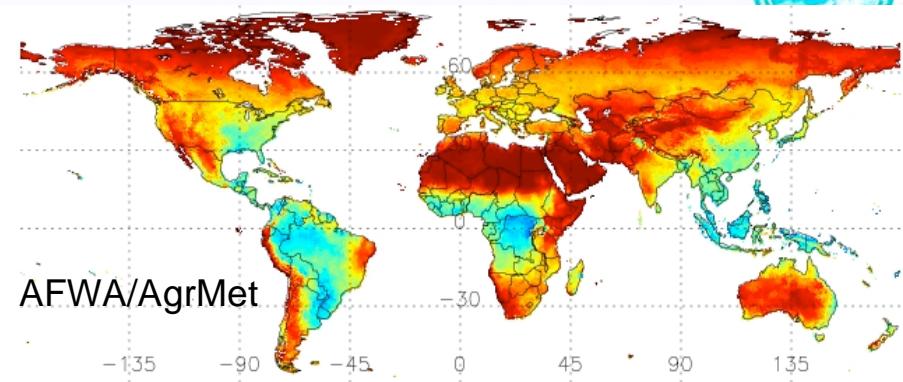
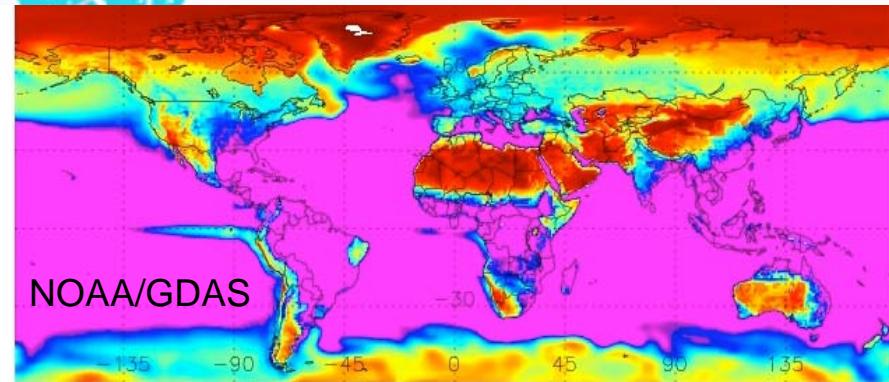
- ALEXI = Atmosphere-Land Exchange Inverse Model
- Two source models partition surface temperature and fluxes between the soil and canopy
- Inputs: GOES based time-differential surface temperature, MODIS or AVHRR fractional vegetation cover
- Product is 10 km resolution over US



Matt Rodell
Hydrological Sciences Branch, NASA GSFC



Modeled ET, Annual Mean (mm/yr)



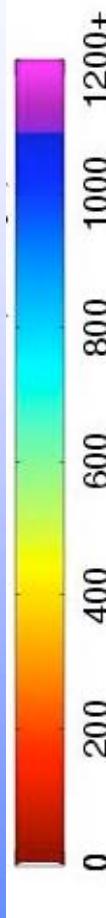
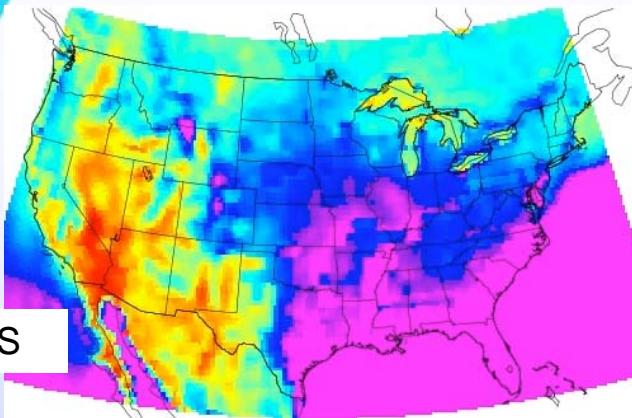
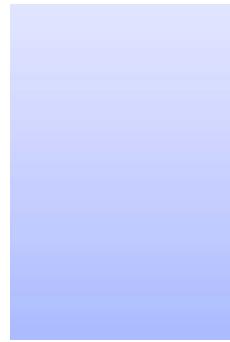
Matt Rodell
Hydrologic Sciences Branch, NASA GSFC



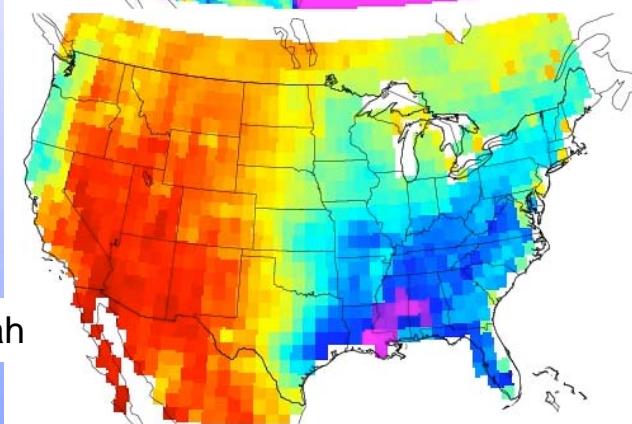
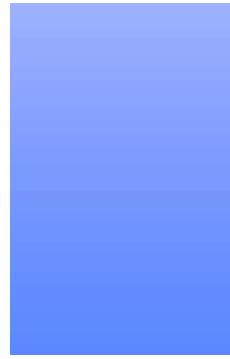
Modeled ET, 2003 (mm/yr)



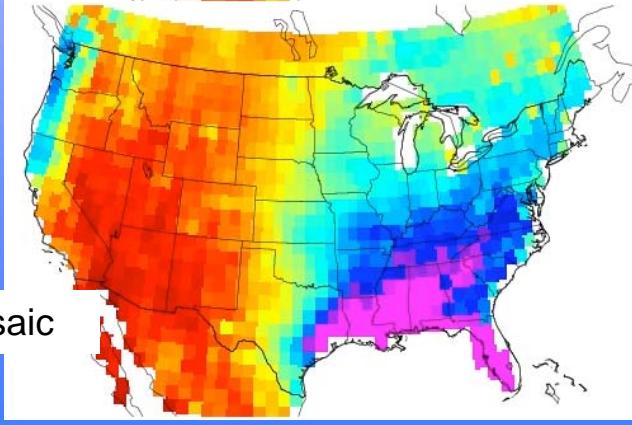
NOAA/GDAS



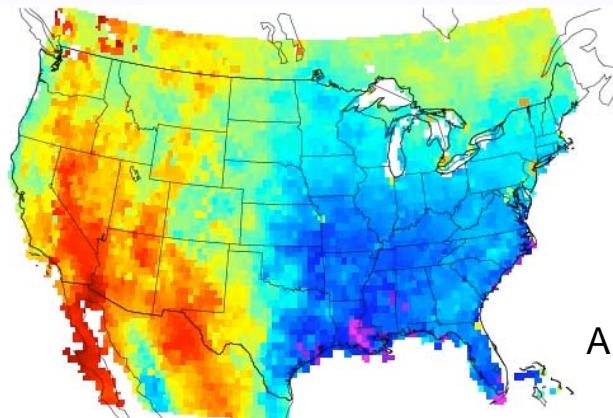
GLDAS/Noah



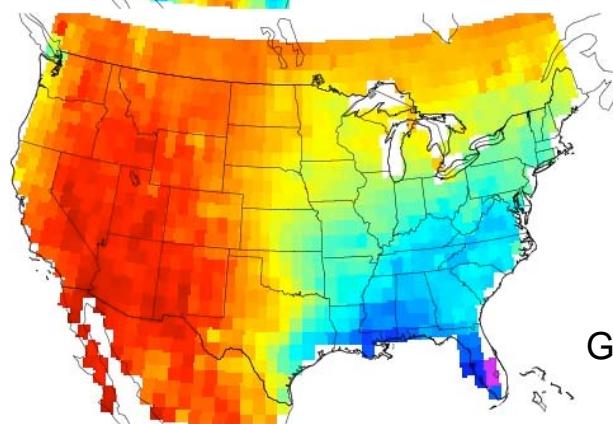
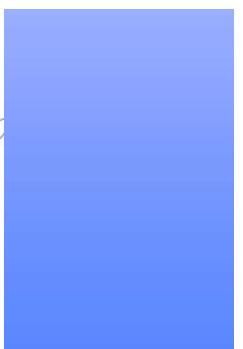
GLDAS/Mosaic



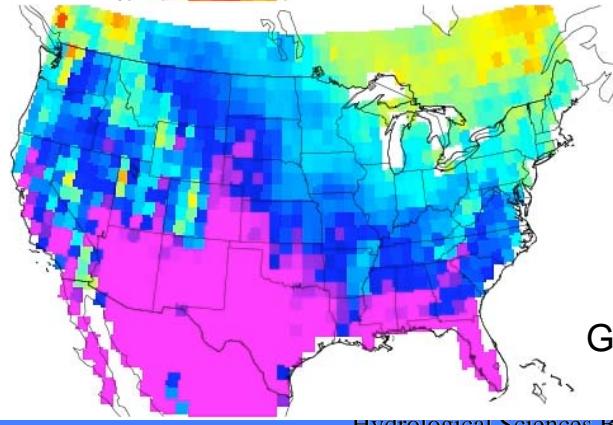
AFWA/AgrMet



GLDAS/CLM2



GLDAS/VIC



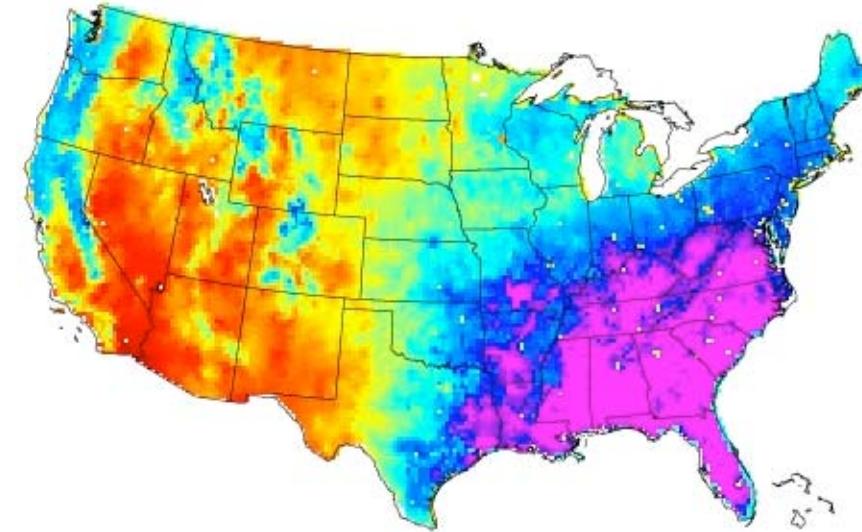
Matt Rodell
Hydrological Sciences Branch, NASA GSFC



Modeled ET, 2003 (mm/yr)



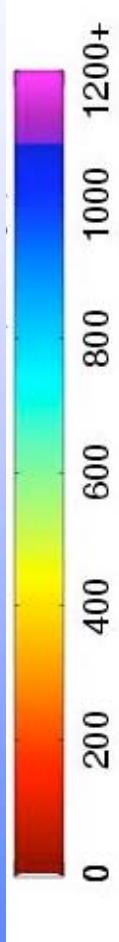
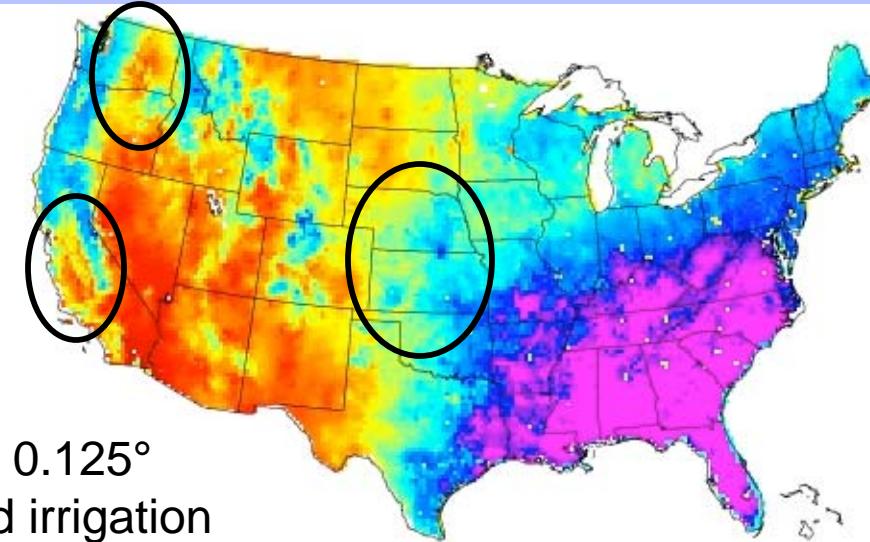
NLDAS/Noah
0.125° control



MODIS-derived
irrigation intensity



NLDAS/Noah 0.125°
with simulated irrigation

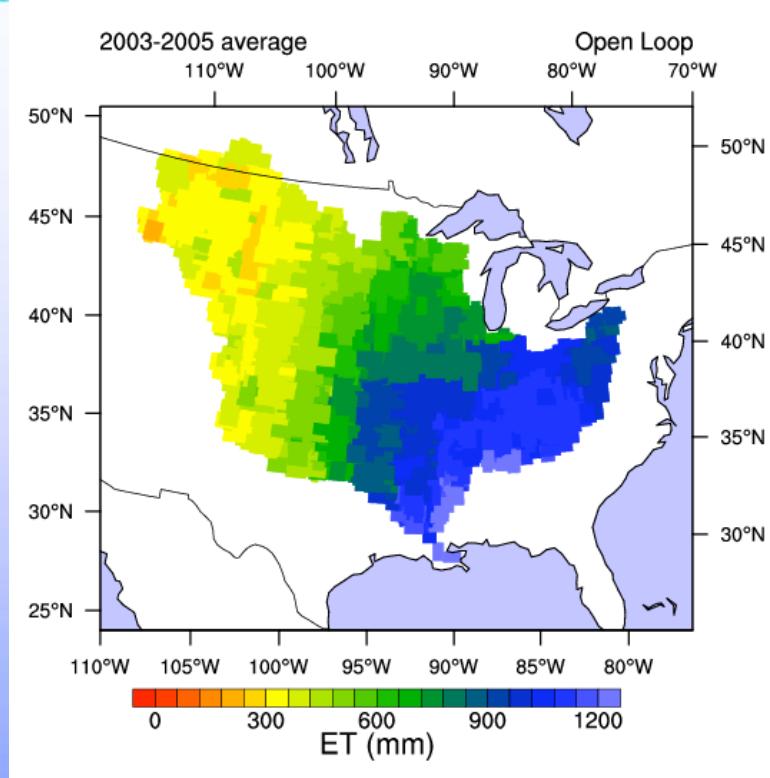


From Ozdogan, Rodell, and Kato, *in preparation*

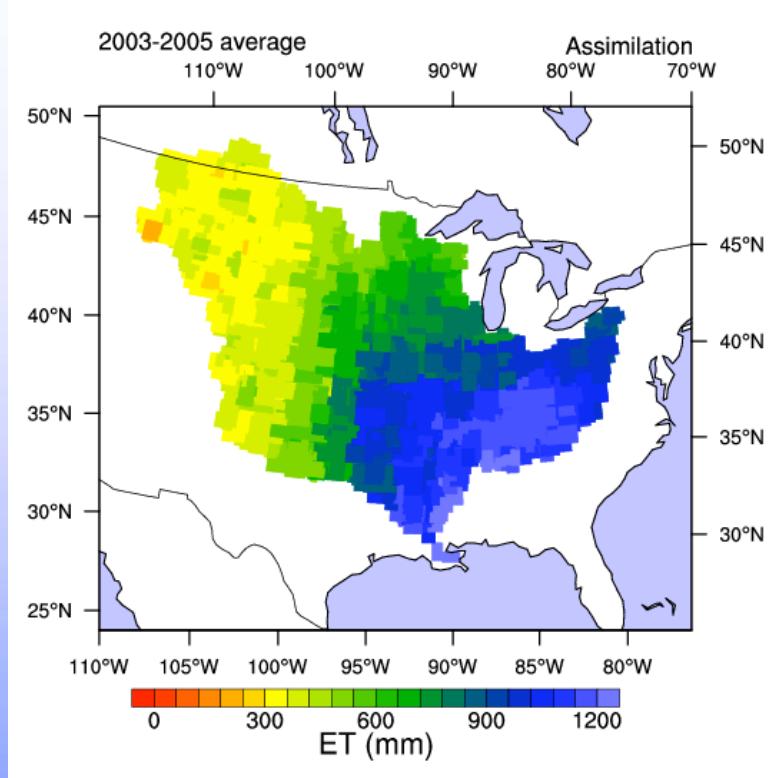
Matt Rodell
Hydrological Sciences Branch, NASA GSFC



Modeled ET, 2003-05 (mm/yr)



Catchment LSM, open loop



Catchment LSM with GRACE
water storage data assimilated via
an ensemble Kalman filter

From Zaitchik, Rodell, and
Reichle, JHM, submitted

Matt Rodell
Hydrological Sciences Branch, NASA GSFC



ET as a Water Balance Residual



Evapotranspiration (ET) estimated
using a terrestrial water budget:

$$ET = P - Q - \Delta S$$

Observation based precipitation product

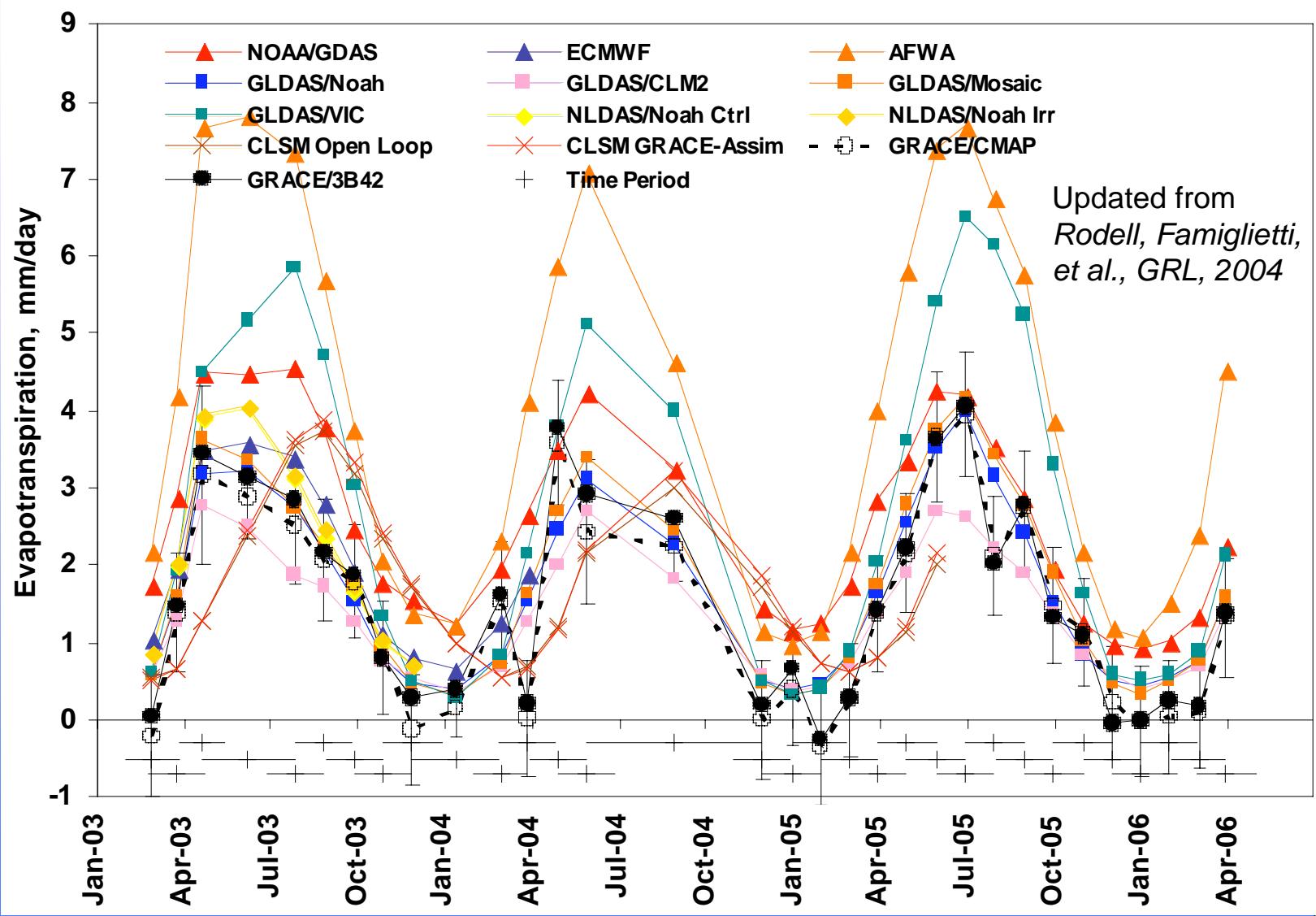
River runoff observations

From GRACE





Comparison of ET Estimates Over the Mississippi River Basin

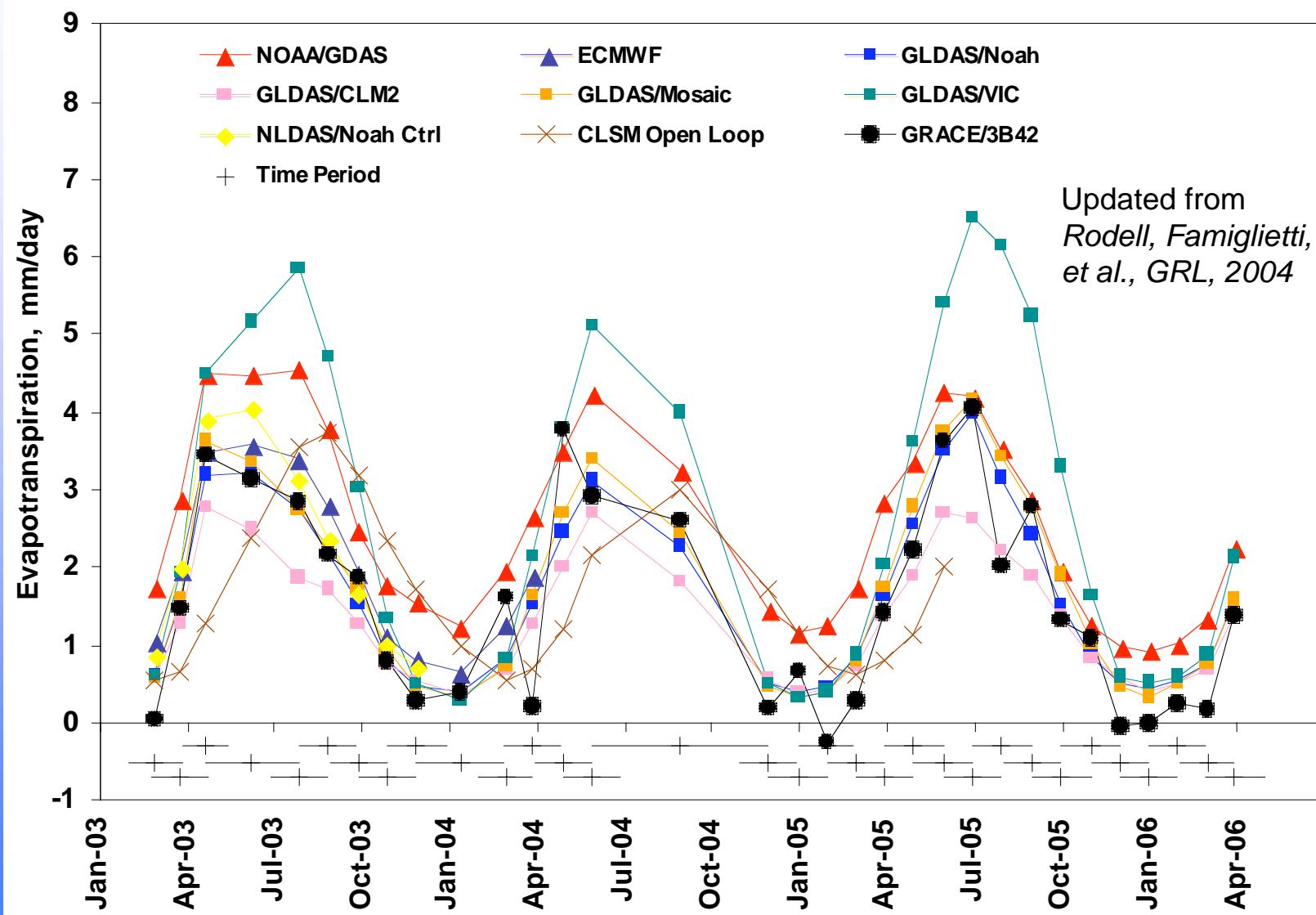


Matt Rodell

Hydrological Sciences Branch, NASA GSFC



Comparison of ET Estimates Over the Mississippi River Basin



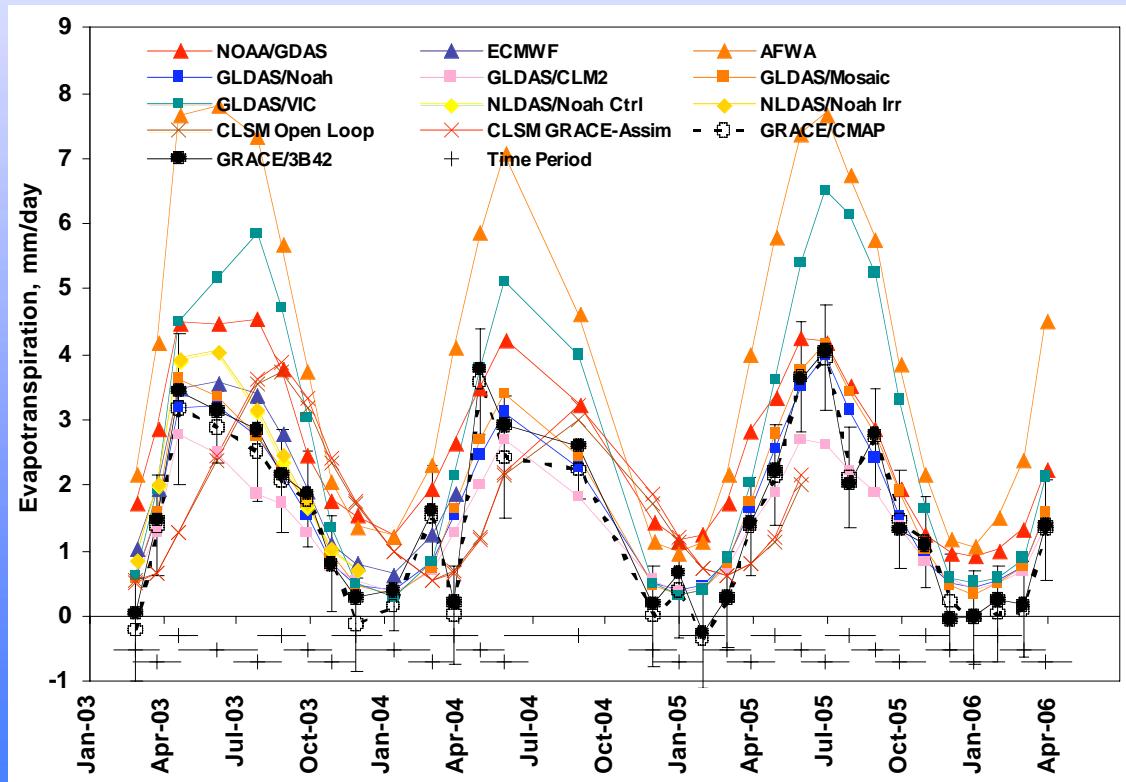
Updated from
Rodell, Famiglietti,
et al., GRL, 2004



Comparison of ET Estimates Over the Mississippi River Basin



	GRACE/ 3B42	GRACE/ CMAP	NOAA/ GDAS	ECMWF	AFWA	GLDAS/ Noah	GLDAS/ CLM2	GLDAS/ Mosaic	GLDAS/ VIC	NLDAS/ Noah	Catchment LSM
Mean	1.53	1.40	2.53	1.99*	3.96	1.64	1.34	1.75	2.64	2.19*	1.64*
Bias		-0.13	1.00	0.47	2.44	0.12	-0.19	0.22	1.12	0.44	0.02
Corr. Coef.		0.99	0.90	0.91	0.91	0.92	0.92	0.92	0.89	0.97	0.45



Matt Rodell

Hydrological Sciences Branch, NASA GSFC



Conclusions



- Evapotranspiration is difficult to estimate, particularly at large scales, hence regional to global maps from different sources diverge significantly
- Integration of satellite observations within sophisticated and evolving (i.e., not stagnant) models may be the best hope for producing accurate maps of ET
- GRACE-driven water budget analyses are valuable for identifying ET estimation biases and should be included in all current and future ET/water budget studies (however, the (in)availability of runoff data is a limitation)